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Chasing the Sun – The In-Flight Evaluation of an Optical Head Tracker

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Chasing the Sun-
In-flight Evaluation of an Optical Tracker

21 April 2006

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Good morning,

I'm Mike Sedillo from the Air Force Research Laboratory at Wright-Patterson AFB in Dayton Ohio.

I will be briefing highlights from our paper titled "Chasing the Sun-In Flight Evaluation of an Optical Tracker" on behalf of the my fellow authors Mr. David Harris and Mr. Doug Franck

Overview

- Introduction
- Background
- System Description
- Experimental Design
- Aircraft Selection/Modification
- Data Collection
- Flight Planning
- Safety & Human Considerations
- Skid Design
- Flight Report
- Conclusion

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After a brief introduction, I'll provide some background on tracker applications in the military and proceed to describing the tracker system used in this test.

Experimental Design will be discussed as well as the details involved with selecting and modifying our test aircraft.

I'll continue with some detailed information on how we collected various types of data as well as the unique considerations during the flight planning phase.

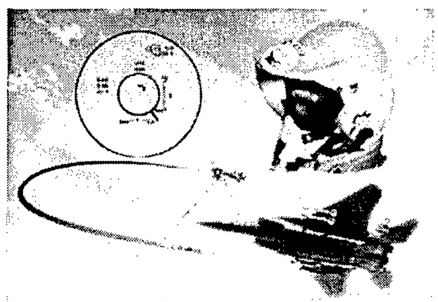
Flight and Human-related safety considerations will be addressed along with some information on test skid design

I will conclude with a brief description of our actual flight tests

Introduction

Airborne Tracker applications

Optimize helmet-mounted display systems effectiveness
- Aim weapons
- Acquire mission-critical information
- Receive self-protection prompts by looking at target through visor
- Accurately measure pilot's line-of-sight (LOS) angles
- Permit precision guidance of weapons
- Enable intra-cockpit cueing
- Maximize situation awareness



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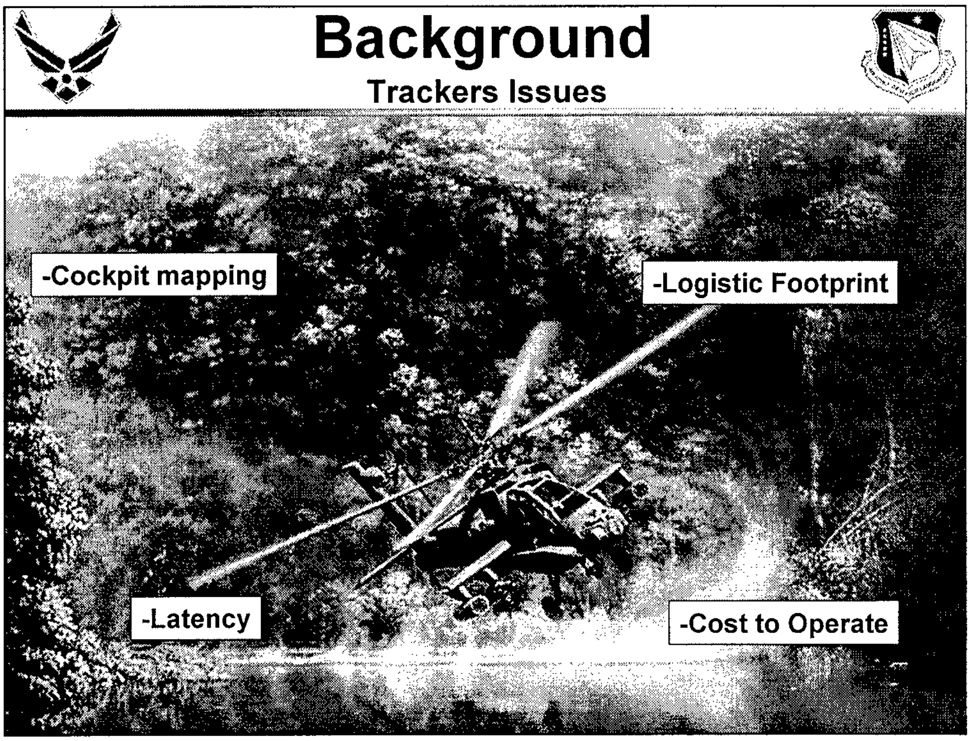
Head trackers have become an important tool in modern combat aircraft.

They are used to:

- AIM WEAPONS
- ACQUIRE MISSION CRITICAL INFORMATION
- RECEIVE THREAT WARNING PROMPTS
- MEASURE PILOTS LOS FOR PRECISION WEAPON APPLICATIONS
- ENABLE INTRA-COCKPIT CUEING
- MAXIMIZE OVERALL SITUATION AWARENESS



Optical trackers, like those installed on the AH-64 Apache, offer a different approach to accomplish similar tasks.

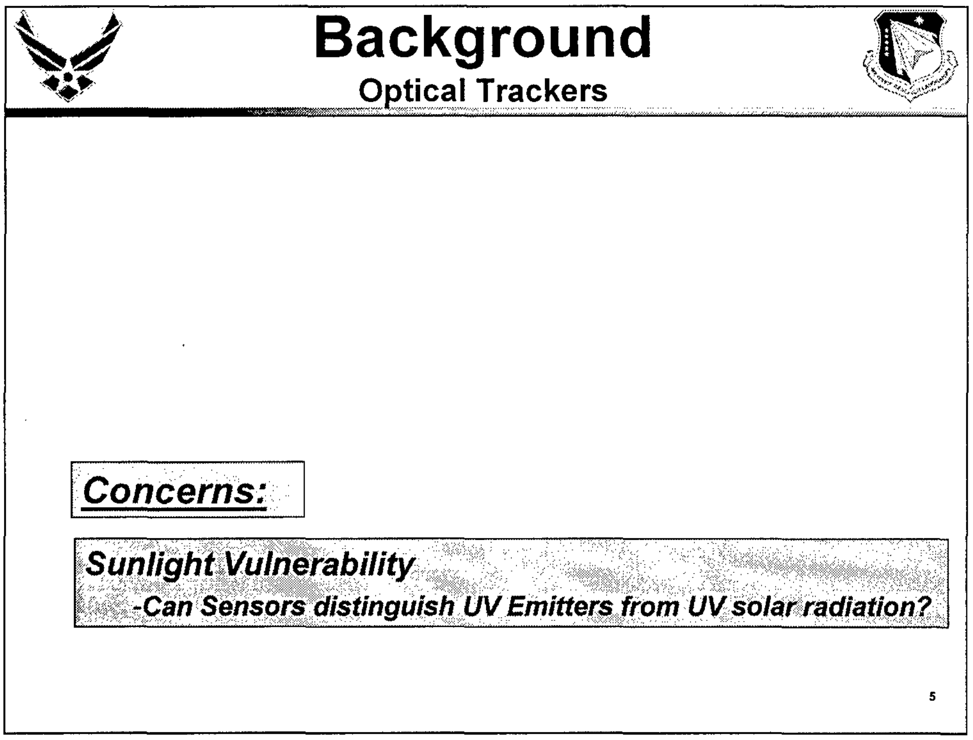
Some tracker issues our group is working to improve upon are

- Cockpit mapping
- Logistic footprint
- Latency and

-Cost to Operate

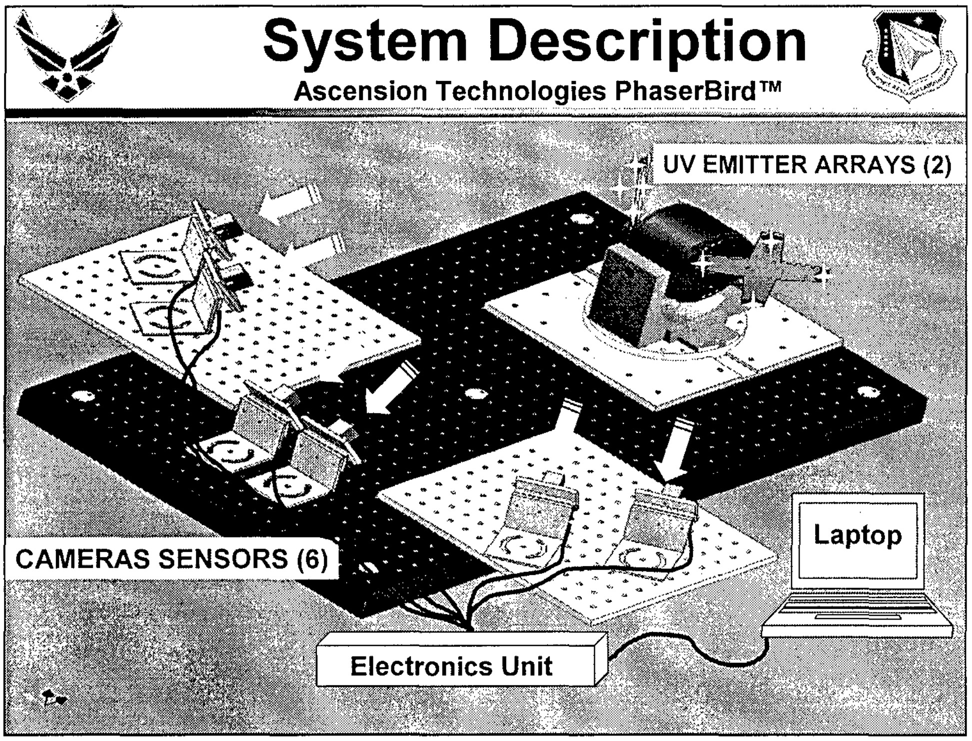
Ascension Technologies based in Burlington Vermont developed an optical tracker under DARPA sponsorship that showed promise in overcoming some of these issues

(TRANSITION) However, there was still some concerns related to optical tracker systems



Since optical systems track position by monitoring the radiated light from the system's emitters, another concern was the systems vulnerability to solar radiation.

Could the optical tracker system distinguish light from it's system emitters when the sensors were saturated with solar energy?



Working with Ascension Technologies, the Air Force acquired an optical tracker system for evaluation.

The PhaserBird in this test utilized six sensor cameras to monitor the Ultra-Violet light emitted from two emitter arrays. Each Array had four emitters mounted on a cross-like bracket.

These components were tied to an electronics unit that fed into a laptop computer to provide real-time positional feedback on the tracker system.

Experimental Design

- **Goal:** Assess tracker performance under solar flight conditions
- **Approach:** Compare performances under "mundane" solar conditions to extreme solar (flight) conditions
- **Requirements:**
  - Data points must be repeatable for comparison
  - Must be able to measure light exposure under various conditions
  - Compensate for vibration induced displacement

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The primary GOAL of our test was measure the trackers accuracy and ruggedness when operating under dynamic flight conditions.

Our APPROACH was to compare the trackers performance when operated in low light conditions to that under more intense solar conditions.

This was important to assess the systems potential to be utilized in a fighter aircraft operating at high altitudes.

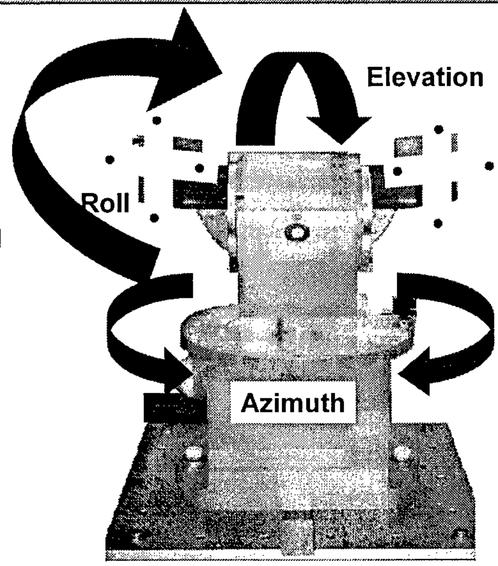
Some basic REQUIREMENTS for this approach was for repeatable positional reference data points.

We also needed the ability to measure the light to which the system was being exposed as well as the vibration displacement from the aircraft

Experimental Design

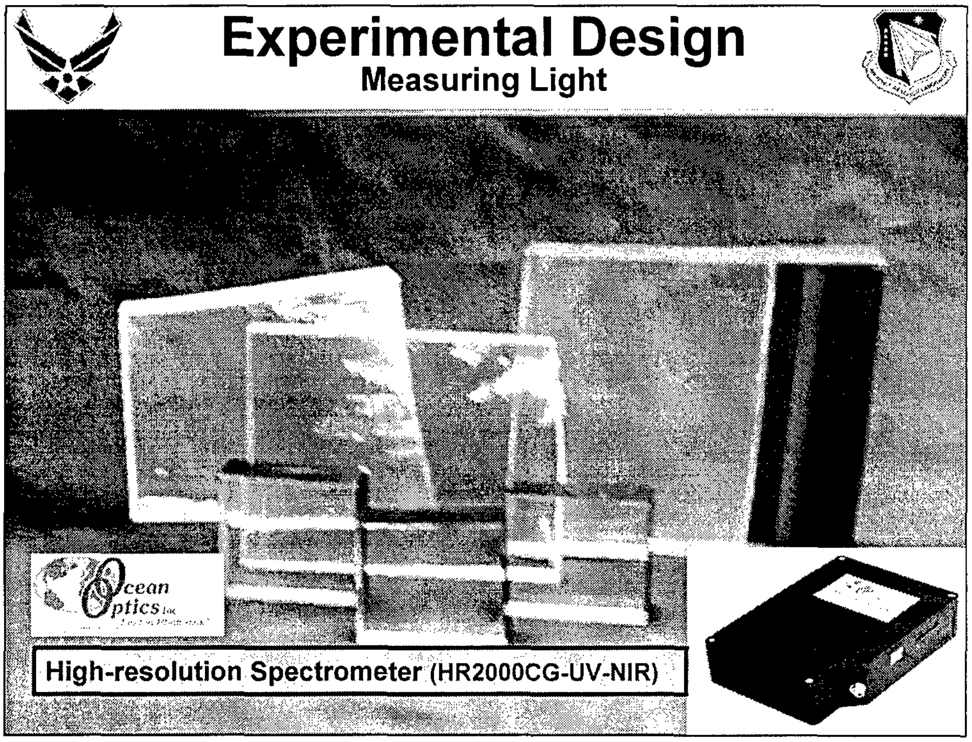
Repeatability

- **6 Degrees of Freedom Gimbal**
  - **Repeatable positions**
  - **5° Increments**



To achieve the REPEATABILITY, a gimbal with 6 Degrees of Freedom was used.

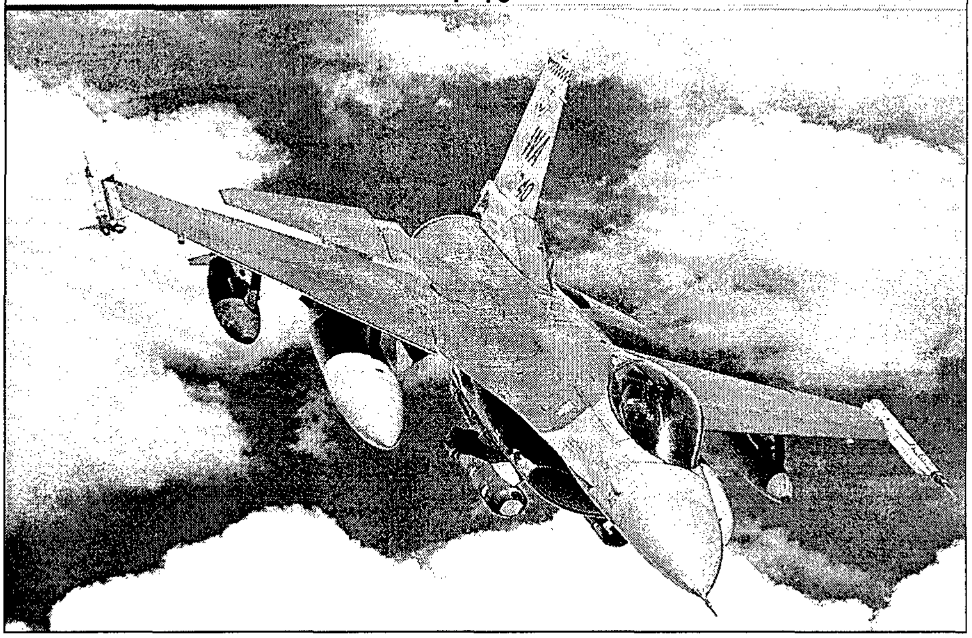
The Gimbal could be rotated in three axis providing ELEVATION, ROLL and AZIMUTH adjustments in 5 degree increments.



An high resolution spectrometer from Ocean Optics was used to measure the transmissivity of various fighter canopies.

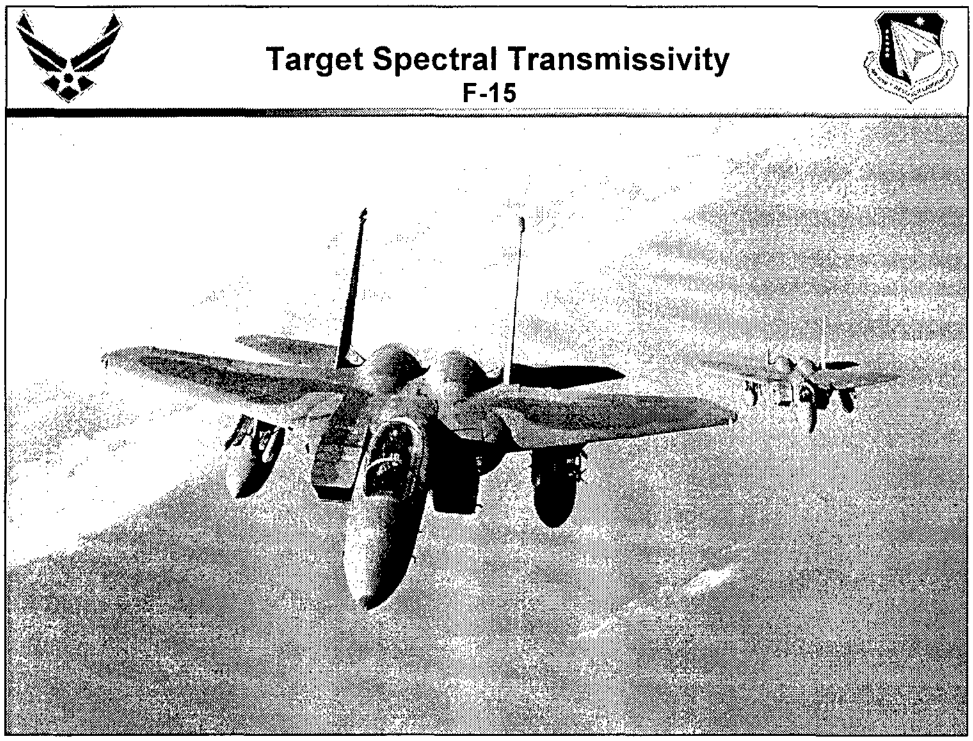
Although a high-solar environment was the goal for the test, it was important to create a representative flight test environment that the tracker would actually be employed

Target Spectral Transmissivity
F-16



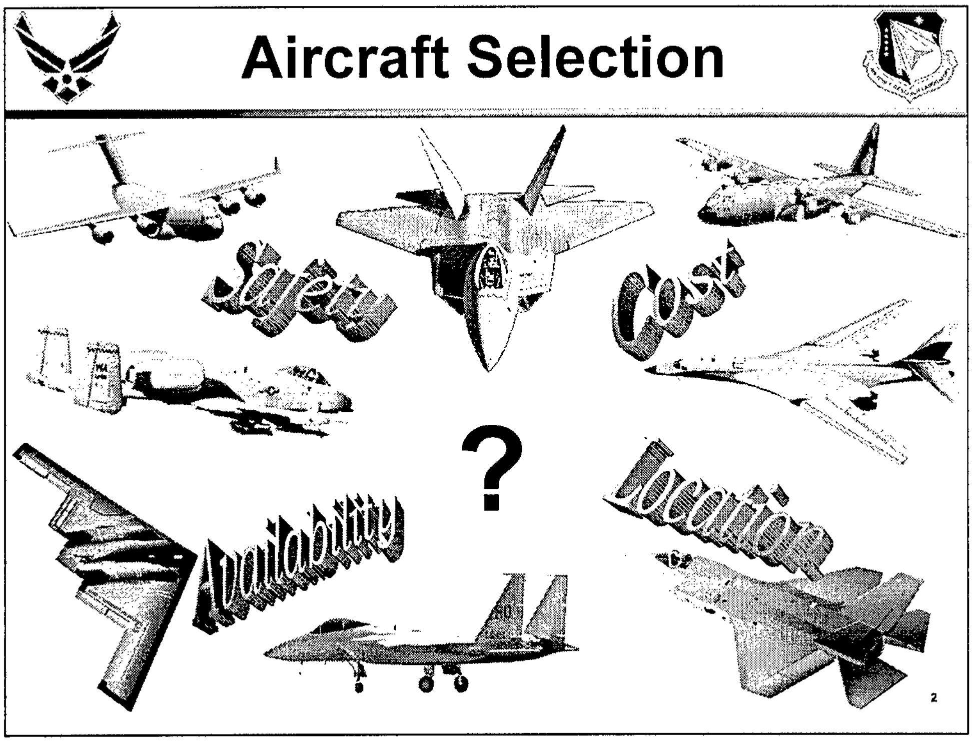
Transmissivity was measured in both an F-16 canopy,

as well as..............



…..in an F-15 canopy.

Although there are many variants of these canopies, we were primarily interested in approximating the representative target environment

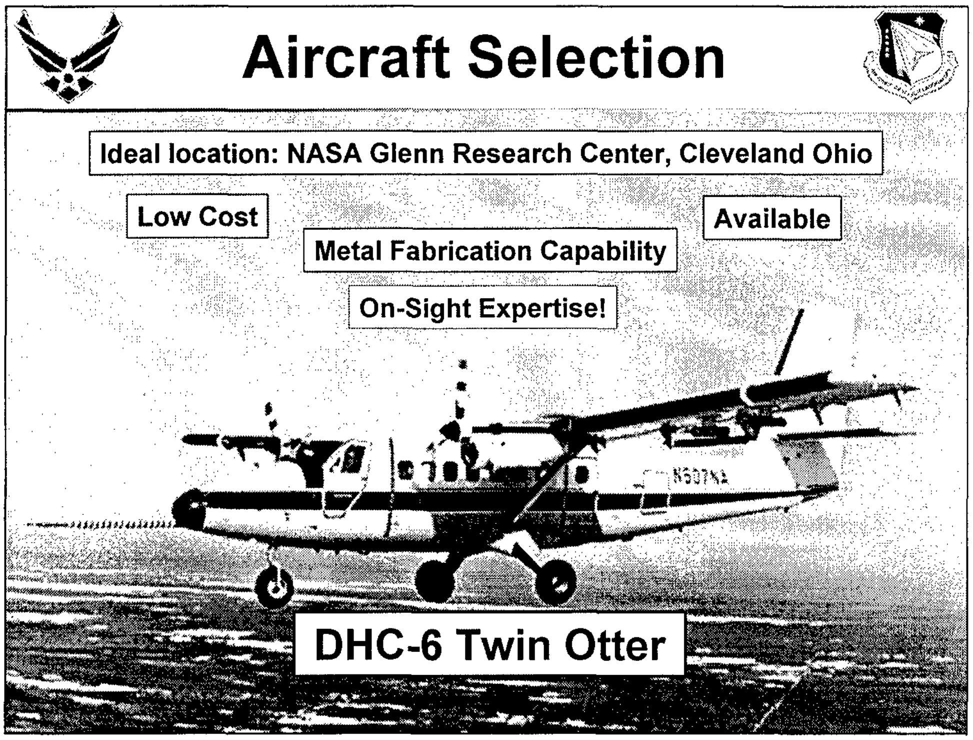


As we began exploring flight platforms to conduct our test, primary factors for consideration were SAFETY, COST, AVAILABILITY and LOCATION of the assets

With a limited budget and short schedule to conduct the evaluation, we quickly eliminated military platforms

Having to qualify our system for flight in an aircraft with ejection seats was cost-prohibitive

We began considering options outside the military



We turned to NASA-Glenn Research Center in Cleveland Ohio

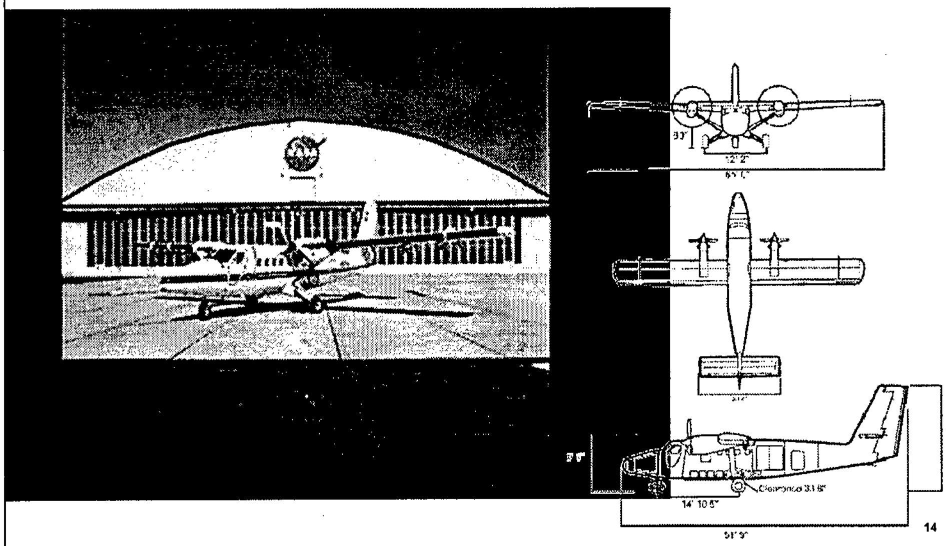
Located only three hours from Dayton, their location was ideal.

With icing research suspended during the summer, their fleet was available.

NASA-Glenn also had a full metal fabrication capability with on-sight experts to assist with any aircraft modifications that we found highly attractive.

Our initial concept was to use their DHC-6 De Havilland Twin Otter with its ample space for researchers and equipment and lack of ejection seats

Aircraft Evaluation



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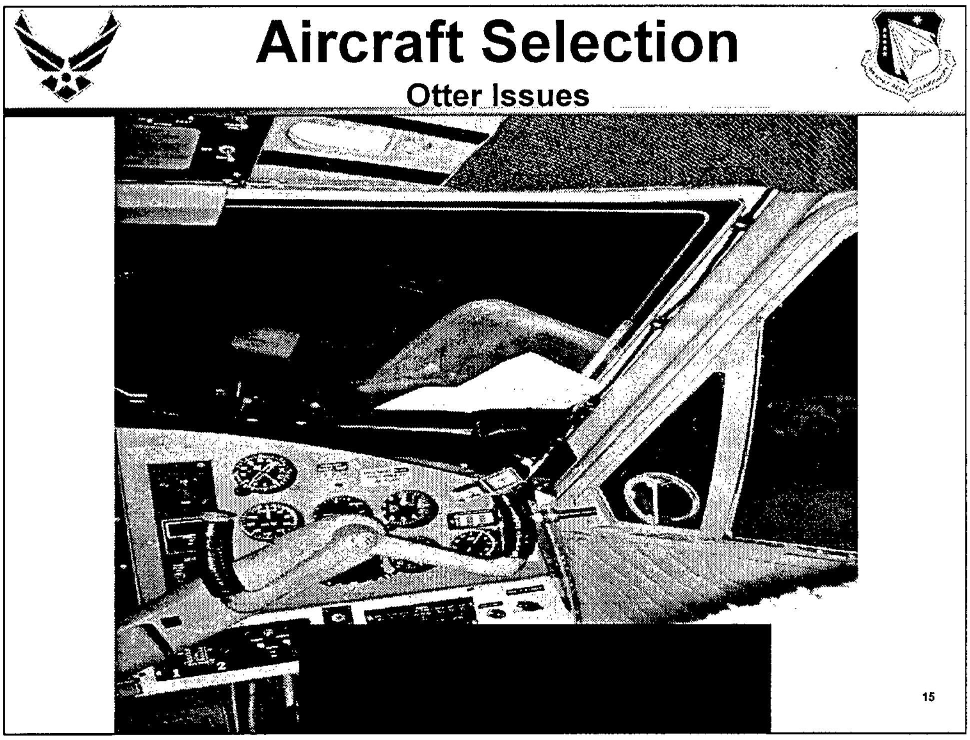
Since the only one pilot was required to fly the Otter during non-ice research missions, our initial concept was to mount the gimbal in the front seat to allow for maximum solar exposure

With agreements in place between AFRL and NASA-Glenn, we traveled to Cleveland to visit NASA-Glenn Research Center to evaluate the Twin Otter for applications and begin the formal experiment design

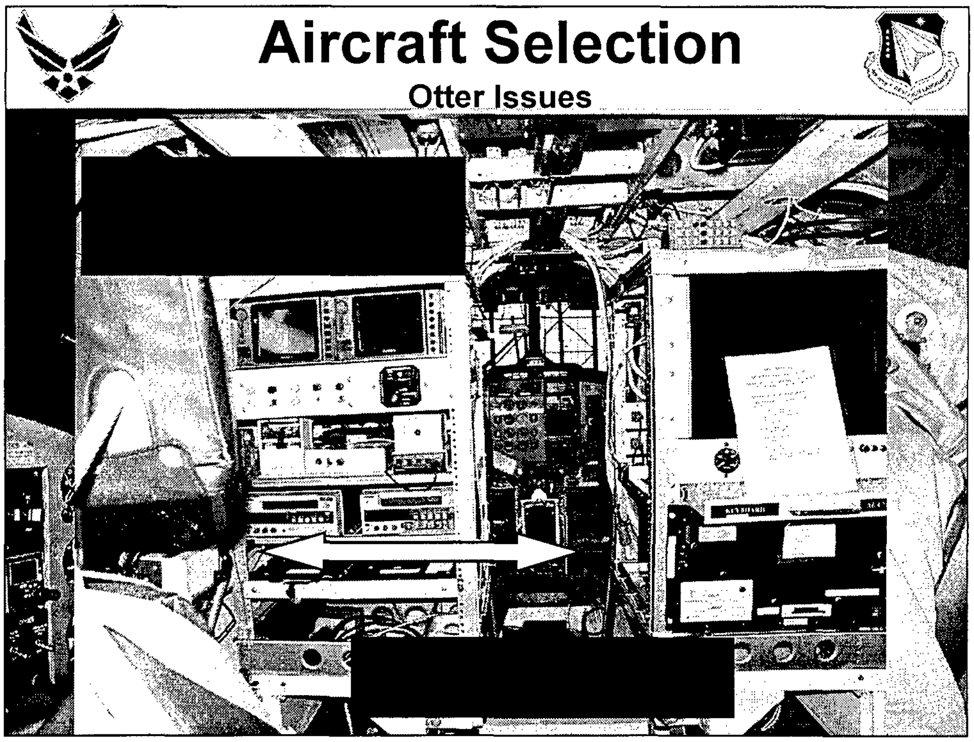


Upon initial evaluation of the Otter, we immediately discovered some major issues with our test concept.

The windscreen was not fighter-aircraft representative as it lacked sufficient solar attenuation.

This condition was potentially correctable with the application of UV film

(TRANSITION) However new problems quickly presented themselves



The idea of placing the gimbal in the front seat was quickly abandoned.

Inadequate space would restrict movement of the yoke assembly

(CLICK)

As well as make in-flight gimbal adjustments difficult.

Researchers seated in back would have to traverse a very narrow walkway to gain access to the gimbal

(TRANSITION) We abandoned the Twin Otter as a flight option an began exploring NASA-Glenn's other assets

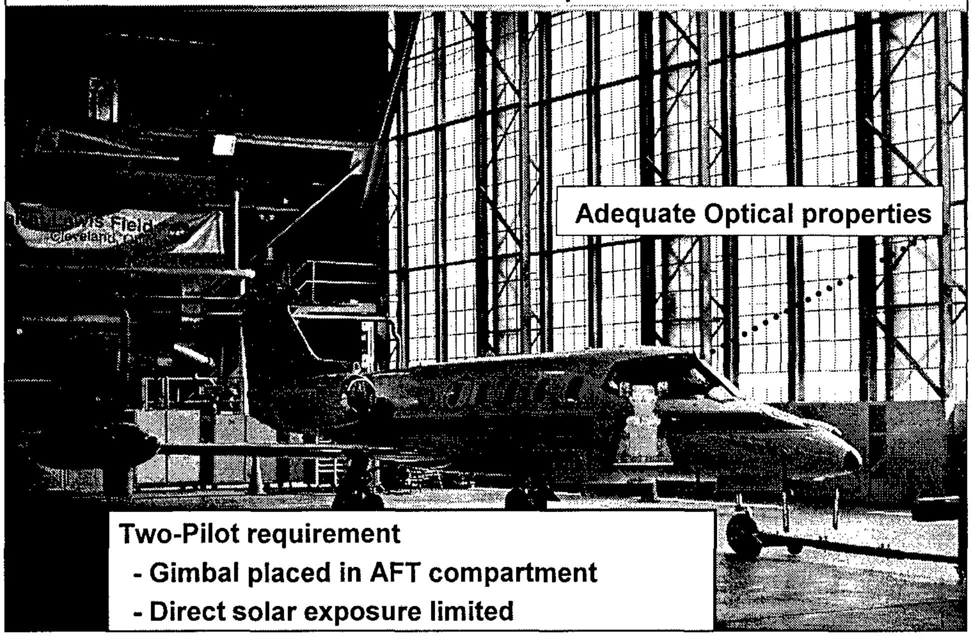
An S-3 Viking was available with adequate space and desirable windscreen characteristics

However, this aircraft was rejected since it had ejection seats and would impose excessive safety requirements for both personnel and equipment

(TRANSITION) We then began considering NASA-Glenn's Lear Jets

Aircraft Selection

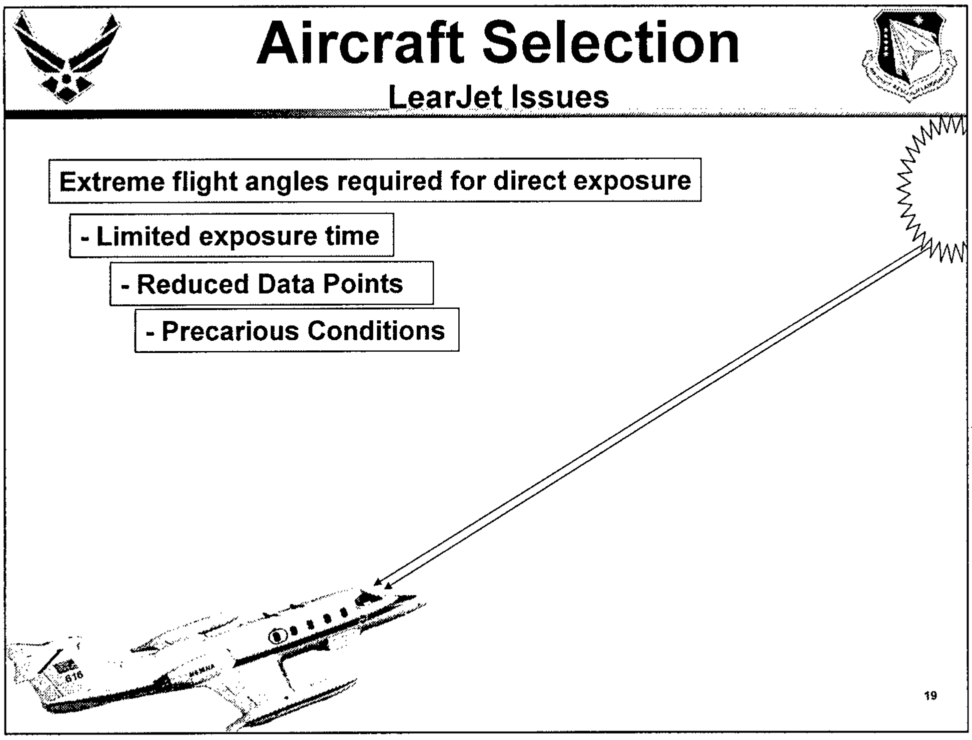
Lear Jet 25 Option



The Lear Jets had excellent optical qualities however our idea of placing the gimbal in the front seat was a non-option since regulations require two pilots during all aspects of flight

We discussed a concept of placing the gimbal in the aft passenger compartment

(TRANSITION) Although there was sufficient room in this area, new challenges were presented



Placing the gimbal in the aft compartment would require the pilots to fly directly at the sun at a high angle of attack in order to achieve direct solar exposure on the tracker sensors.

Although possible, this flight profile could only be sustained for a very limited time before having to descend for another run.

The abbreviated runs would result in reduced data points as well as precarious conditions collecting data in the back

(TRANSITION) We re-approached the Twin Otter with a new concept

Aircraft Selection

Otter Reconsidered

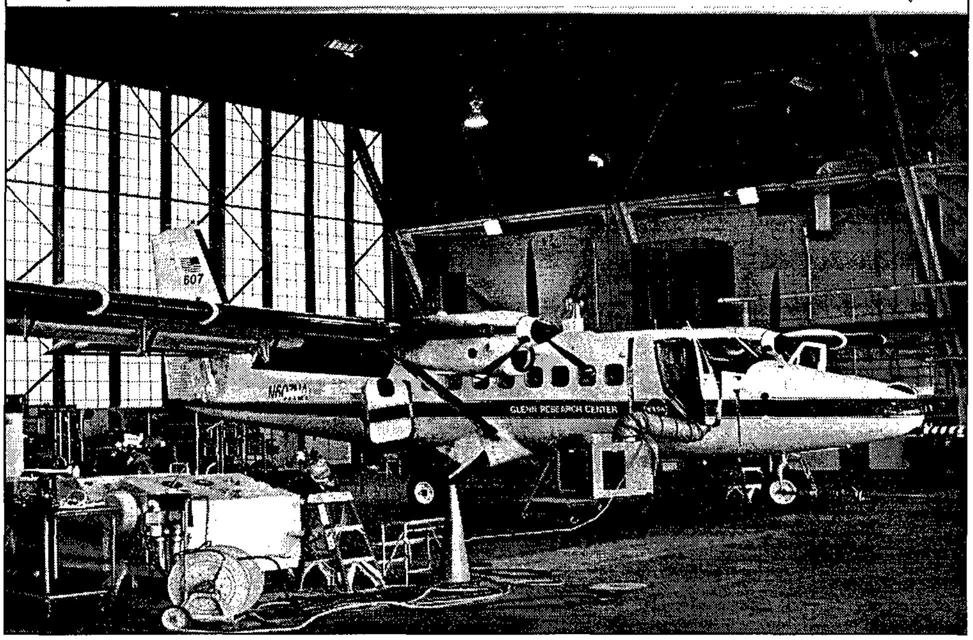
Removing portside doors provides sufficient optical surface
- **Gimbal could be positioned at door**
- **Ample space for researchers and components**
- **Locating suitable "Window" material would be critical**

Removing the portside doors would provide sufficient optical surface for excellent solar exposure

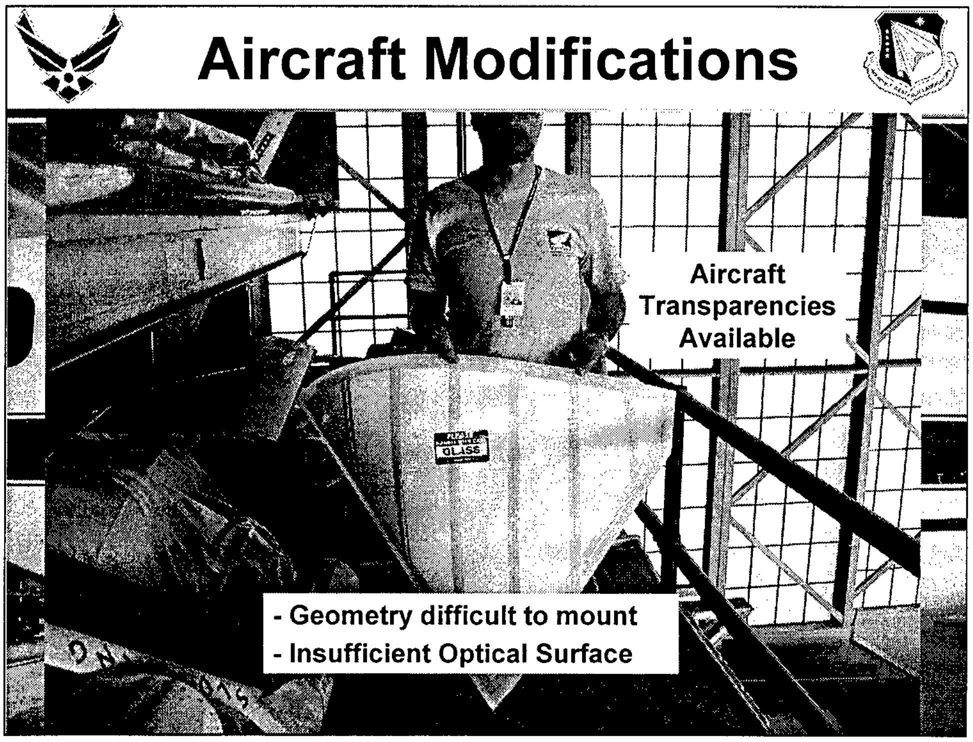
The aft compartment would provide ample space for the researchers and the test equipment

(TRANSITION) Finding a suitable "window" material would be critical

Aircraft Modification



(TRANSITION) Modifications quickly began on the Twin Otter

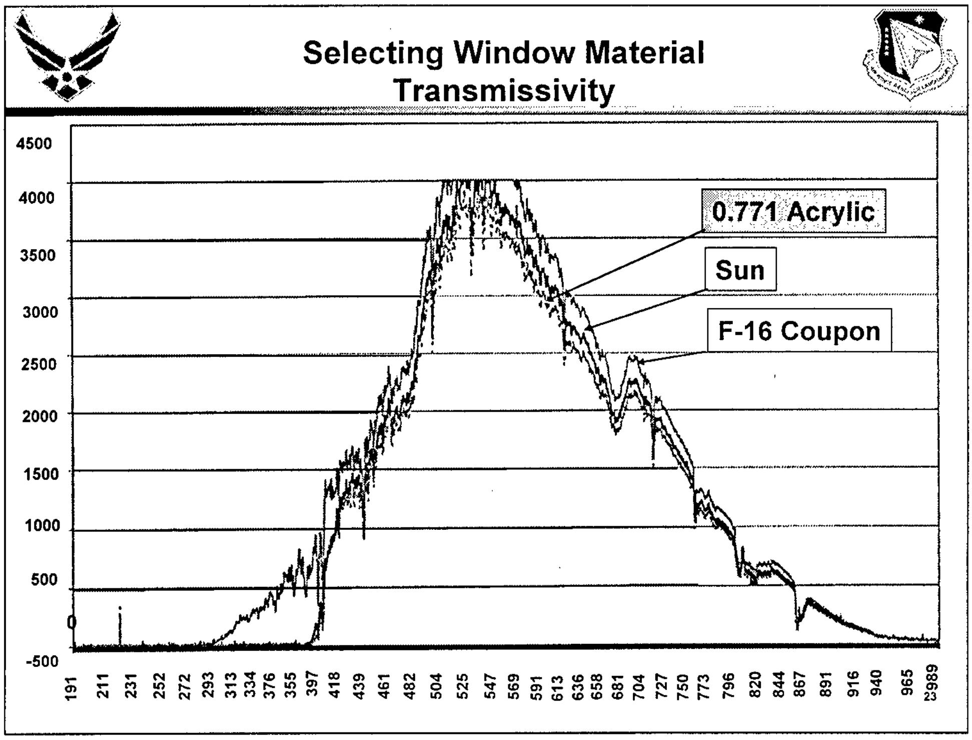


Various materials were considered for the window.

With a limited budget, we explored using existing aircraft transparancies

(CLICK)

However, the geometry of these materials made them difficult to safely install. Their size also reduced the optical surface

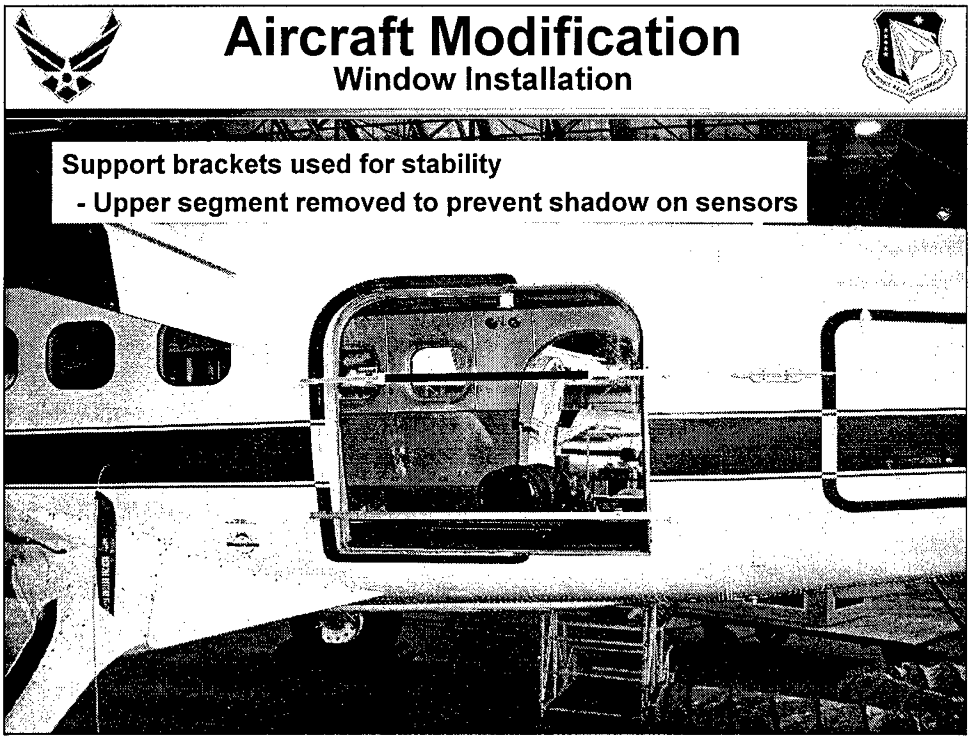


Slide #25

NASA-Glenn engineers located a large Acrylic that was sufficiently thick to withstand the stress of mounting to the aircraft frame.

We found the transmissivity of the sheet closely emulated the characteristics of an F-16 canopy.

(TRANSITION) NASA engineers began planning on how to install the sheet on the Otter



Slide #26

After removing the Twin Otter's doors, the NASA engineers were able to cut the acrylic sheet to fit snuggly in the door cavity.

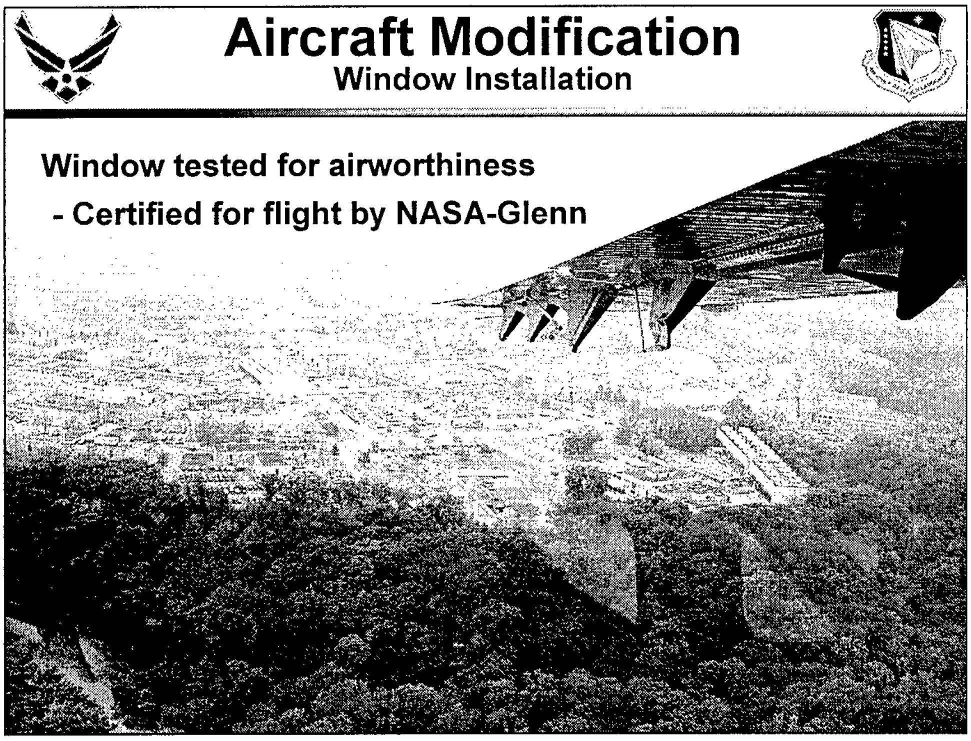
Aluminum brackets were fabricated to attach the sheet to the existing door hinges

(CLICK)

The upper bracket was modified by removing the center section to prevent any shadows from being cast on the tracker receivers.

A sealant was applied to the window edges to prevent engine exhaust from entering the fuselage.

(TRANSITION) Once the modifications were complete, the window was ready to be tested for airworthiness



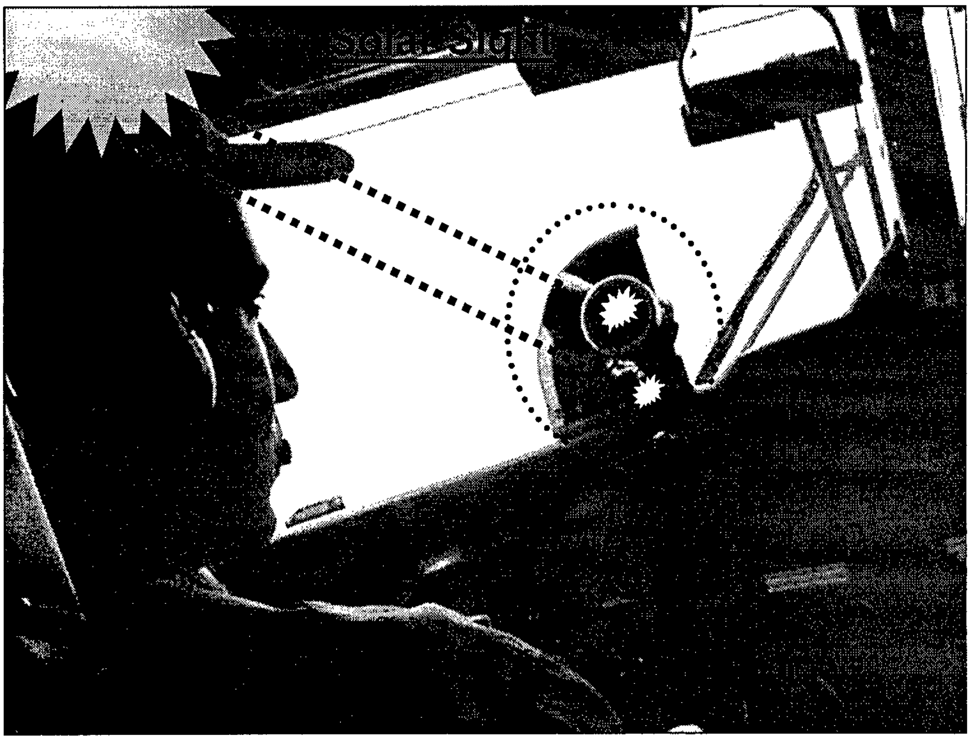
Slide #27

NASA engineers were concerned with how the window would perform when subjected to vibration and torque during flight.

All concerns were put to bed during the airworthiness flight. No significant vibrations were noted. Some **dampening was attributed to the sealant** that was applied to the edges.

NASA Safety engineers issued a formal **<u>flight permit</u>** to utilize the modification….

(TRANSITION) …but other modifications were required



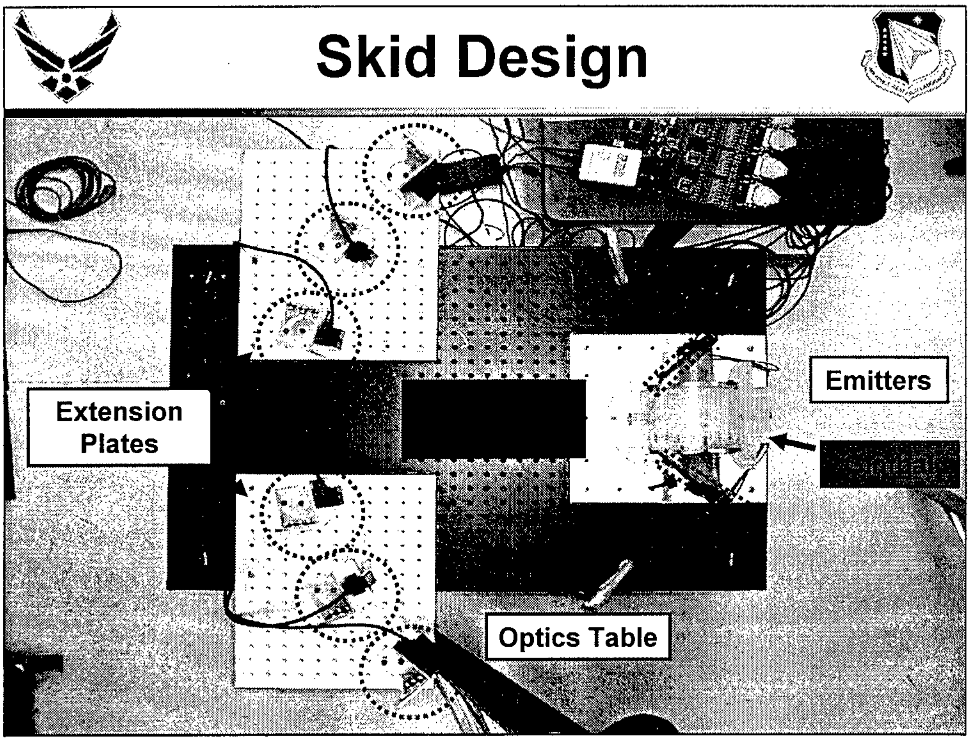
Slide #28

An adjustable solar sight was installed on the aircraft's dashboard allowing the pilot to "aim" the tracker-sensors at the sun. The sight's angle was adjusted to replicate the look-up angle of the tracker sensors.

The pilot would use the sight to adjust the bank angle of the aircraft in order track the constantly rising sun.

With the scope's narrow field, the pilot required excellent airmanship to continuously track the sun-fortunately our pilot, Mr. Jim Demers was up to the task.

(TRANSITION) While the aircraft was being modified, efforts to design the test skid were under way at Wright-Patterson AFB.



Slide #29

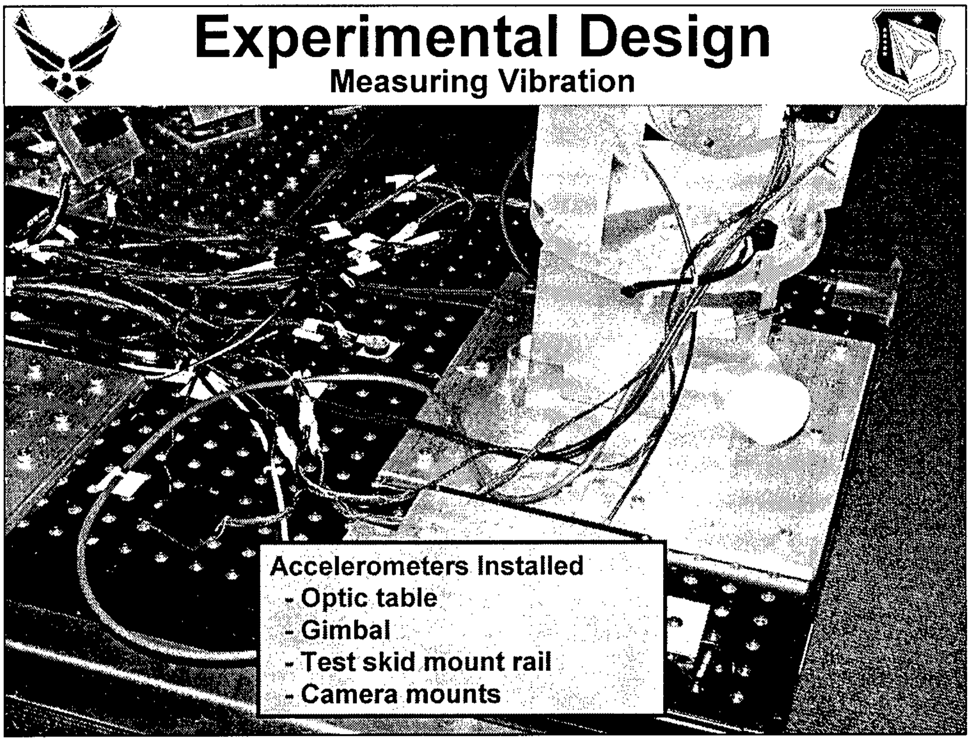
A small optics table served as the base for mounting the test components.

Extension plates were added to allow adequate spacing for the sensor cameras.

The Gimbal was mounted to the table after a height extension as added to the gimbal base. This allowed us to build in a higher look-up angle in the system in order to reduce the bank angle the pilot would have to fly during the test. As the bank angle (or slip) was increased, so too was the aircraft induced vibration

The tracker emitter arrays were mounted on the gimbal at 45 degrees.

(TRANSITION) Components other than the tracker were also attached to the test skid

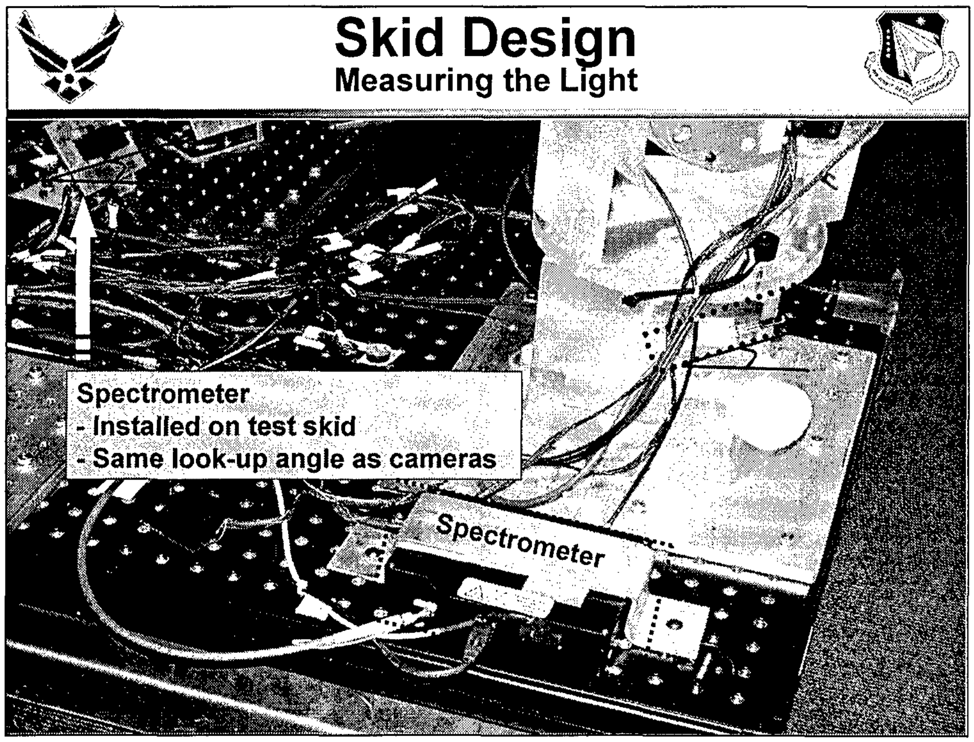


Slide #30

Tri-Axis accelerometers were attached to various locations on the test skid including the optics table, gimbal, test skid mount-rail and the camera mounts.

The data these sensors would provide would enable vibration induced displacement to be factored into the post-flight analysis

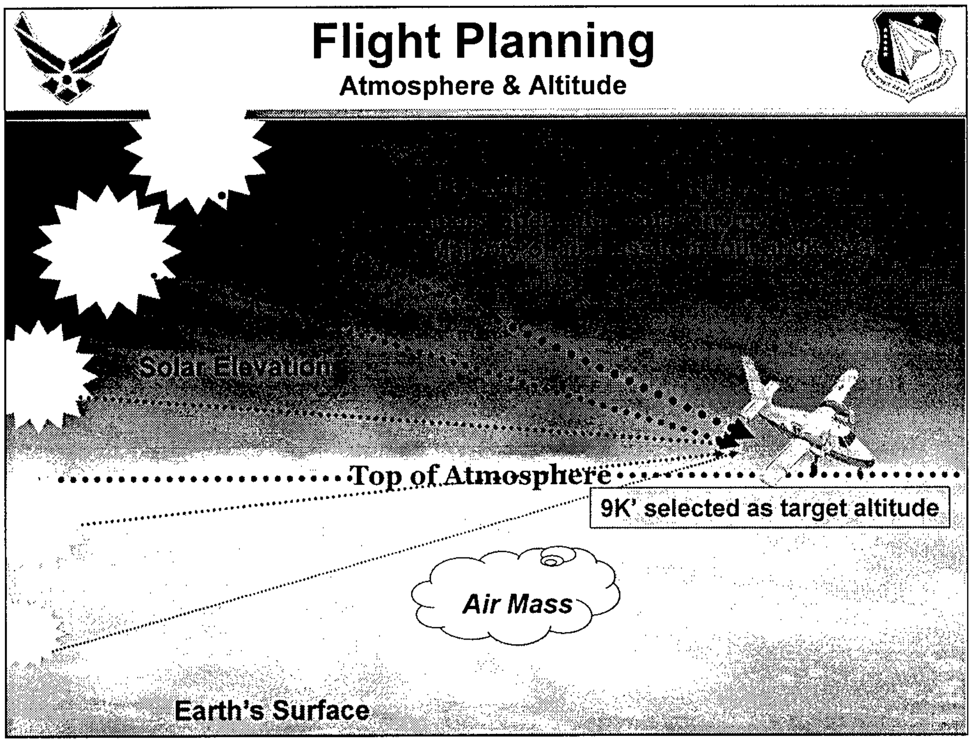
(TRANSITION) In addition to measuring the vibration, we also needed to measure the light beaming through the window.



The spectrometer was installed on the skid with the sensor positioned at the same look-up angle as the tracker's sensors ensuring both were exposed to the same solar energy.

The spectrometer, vibration and tracker systems were **integrated** into a single computer with all data points **time-synchronized** for correlation during analysis.

(TRANSITION) With the test skid designed and fabricated, we began finalizing the flight plan for the tests.

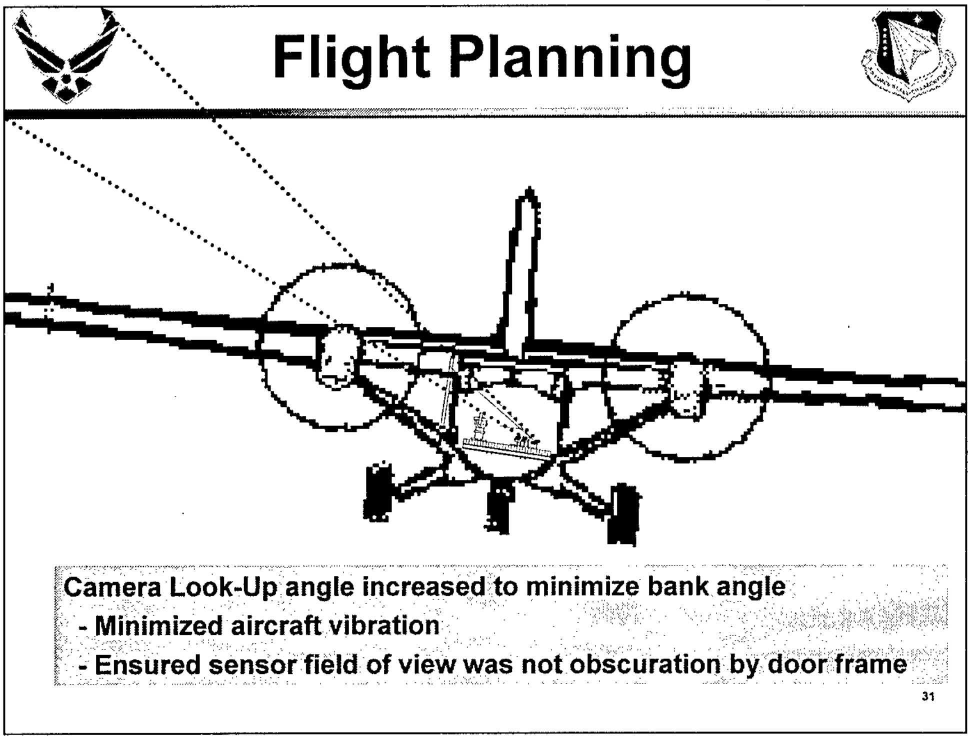


Determining a flight altitude was a primary consideration during the flight planning.

Two factors impacting this decision were **air mass** and **angle of bank** of the aircraft.

In order to maximize the solar exposure, it was important to **minimize the air mass** the sun's energy would have to traverse before reaching the aircraft. A low sun inclination would present a denser air mass that would filter the sun's energy.

A **higher sun-inclination** would provide more concentrated solar energy but would require the pilot to fly at a higher bank angle to maintain contact with the sun. A high bank angle would induce additional vibration potentially effecting tracker accuracy



By choosing 9,000 feet as our test altitude and 1000 am as our test time, we were able to maximize the solar exposure while minimizing the aircrafts bank angle.

(TRANSITION) After finalizing the flight plan, attentions were turned towards preparing the personnel for flight.

Safety

Human Considerations

NASA Personnel Flight requirements:

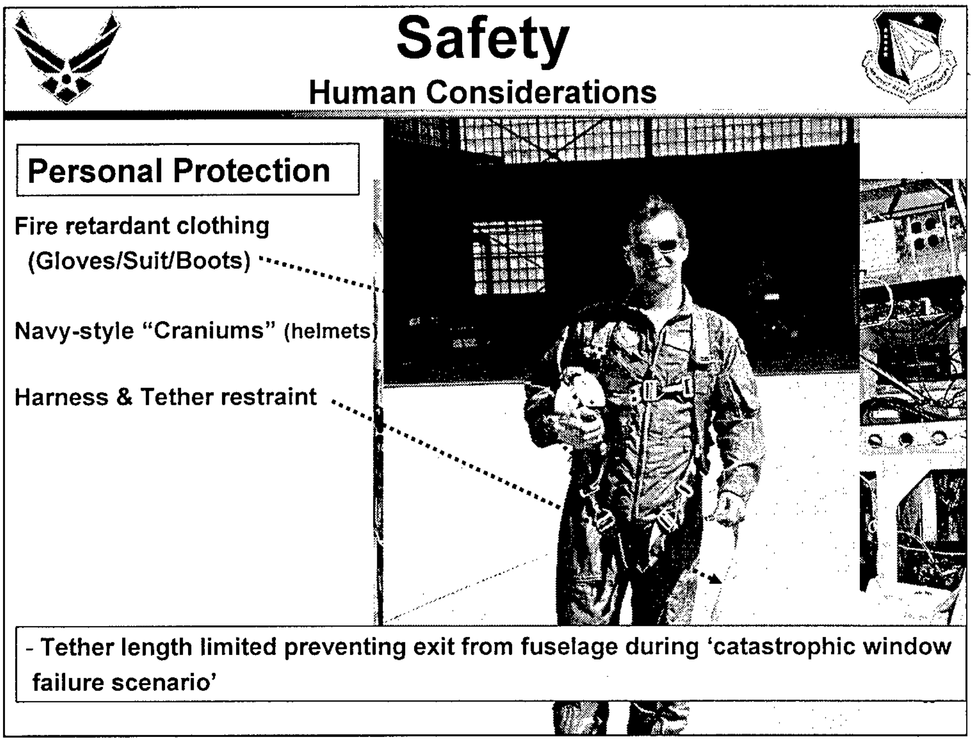
- Class III FAA Flight Physical
- Training:
  - -- Physiological Effects of Flight
  - -- Emergency Egress
  - -- Altitude Chamber

Personnel participating in the test were required to pass a Class III FAA flight physical

They were also provided basic training on the physiological effects of flight as well as hands-on emergency egress training.

One member attended the Navy's altitude chamber training anticipating a more aggressive test plan in the future.

(TRANSITION) Protective gear was also required to enhance safety.

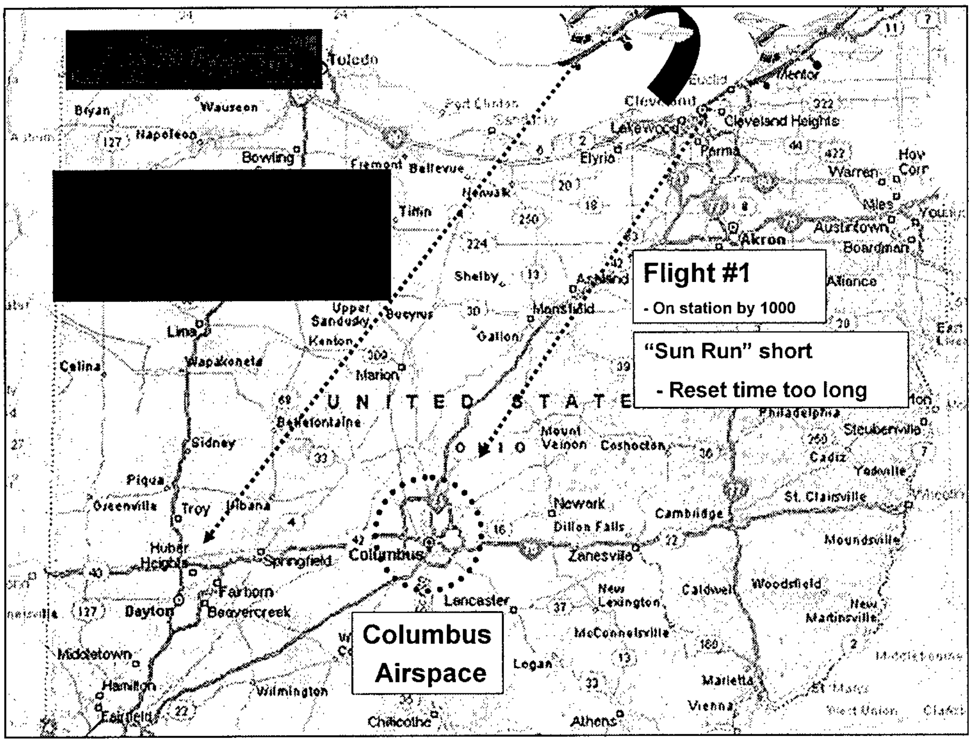


Research personnel were required to wear protective fire clothing including flight suits, gloves and leather boots.

Since they would be moving about the cabin during the test, they were also provided with Navy-style protective craniums or helmets.

Although the window was fully certified for flight, harnesses and tether restraints were required as additional margins of safety in anticipation of a catastrophic window failure. The tethers could be attached to I-bolts positioned throughout the cabin

(TRANSITION) With personnel and hardware tasks accomplished, we were ready for flight.



Our plan during the first flight was to be on-station at altitude by 1000 for our first data collection run.

The weather was clear to we proceeded with the flight.

With the sun rising, a south-south/west route was selected while trying to avoiding the Columbus airspace.

During the first run, we quickly began collecting data with our pilot easily adjusting the aircrafts bank angle with the rising sun.

However, we approached the Columbus airspace sooner than expected and were forced to terminate the run sooner than desired.

We compensated during Flight #2 by taking off 20 minutes earlier to position the aircraft for a more Northerly start point over Lake Erie. This would give us a longer Sun-run with the offset taking us off the path towards Columbus.

We began the second run at 1000 and were able to collect significantly more On-sun data than in Flight #1.

Conclusion

Initial analysis suggests tracker performed exceptionally well

- Robust performance in high light conditions

- Actual test results will be presented at a later date

Test design demonstrated new process for testing optical trackers in representative solar environment

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Questions?

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